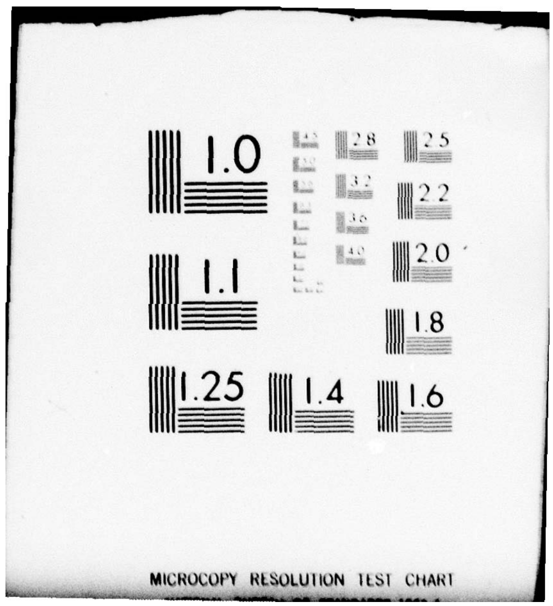
AD-A076 015 DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CE--ETC F/G 20/4
XYZPLOT: A THREE-DIMENSIONAL GRAPHICS PACKAGE FOR FLUID DYNAMIC--ETC(U)
AUG 75 P MORAWSKI
UNCLASSIFIED DTNSRDC/CMD-15/75 NL

| OF |

AD
A076015

END
DATE
FILMED
12-79
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART

LEVEL II


# DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084




# XYZPLOT: A THREE-DIMENSIONAL GRAPHICS PACKAGE FOR FLUID DYNAMICS CALCULATIONS




Paul Morawski


APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED.

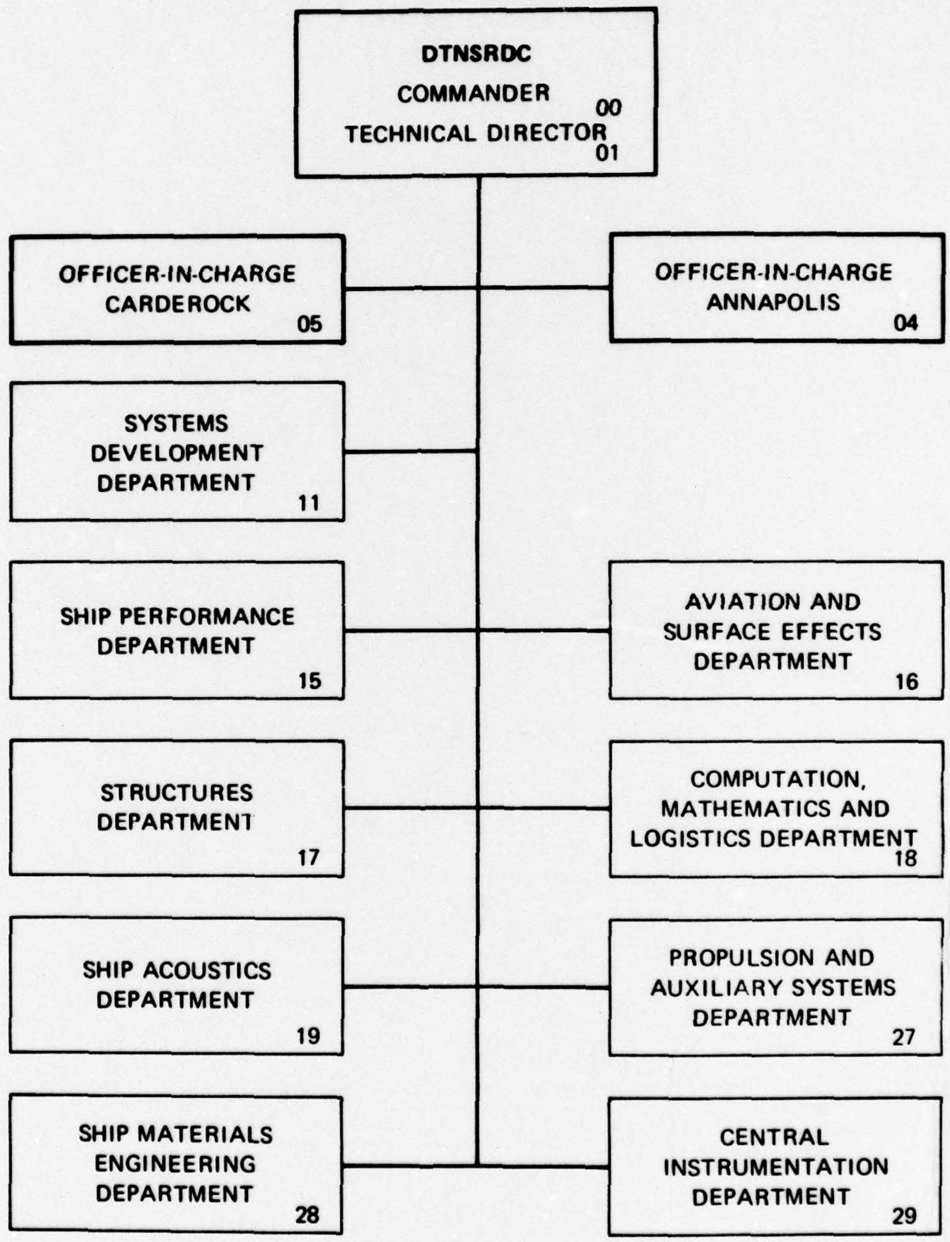
COMPUTATION AND MATHEMATICS DEPARTMENT

DEPARTMENTAL REPORT




August 1975 CMD-15-75

# MAJOR DTNSRDC ORGANIZATIONAL COMPONENTS



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER<br>CMD-15-75 | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle)<br>(6) XYZPLOT: A THREE-DIMENSIONAL GRAPHICS PACKAGE FOR FLUID DYNAMICS CALCULATIONS | | 5. TYPE OF REPORT & PERIOD COVERED<br>6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s)<br>(10) Paul Morawski | | 8. CONTRACT OR GRANT NUMBER(s)<br>(12) 44 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>David W. Taylor Naval Ship Research and Development Center<br>Bethesda, Maryland 20084 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS<br>61153N, R 014 03<br>SR0140301, Work Unit 1843-347 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>(16) SR01403 | | (11) 12. REPORT DATE<br>Aug[redacted]75<br>13. NUMBER OF PAGES<br>41 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)<br>(17) SR0140301 | | 15. SECURITY CLASS. (of this report)<br>UNCLASSIFIED<br>15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

(14) DTNSRDC/CMD-15/75

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer graphics
Potential flow

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

XYZPLOT is a FORTRAN program which generates perspective and orthographic views of arbitrary three-dimensional bodies, as well as streamlines and isobars obtained from potential flow analysis. Hidden surface elements, streamline segments and isobar segments are suppressed. The program input is outlined and several examples are included.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

406 847

slt

TABLE OF CONTENTS


| | Page |
|---|---|
| INTRODUCTION | 1 |
| DESCRIPTION OF METHODS | 2 |
| PROJECTION | 2 |
| Perspective Projection | 2 |
| Orthographic Projection | 5 |
| Conversion to $x_s, y_s$ Coordinates | 7 |
| LOCATING HIDDEN SURFACE ELEMENTS | 8 |
| DETERMINING HIDDEN STREAMLINES | 9 |
| PLOTTING ISOBARS | 9 |
| Determining Pressure Coefficients | 9 |
| Locating Isobars | 10 |
| PREPARATION OF INPUT | 12 |
| BODY DESCRIPTION | 12 |
| Surface Elements | 12 |
| Outline | 17 |
| DATA ORGANIZATION AND FORMAT | 17 |
| Problem Identification and Control Parameters | 17 |
| Body Point Cards | 19 |
| Streamline Points and Isobar Data | 20 |
| User Identification Card | 23 |
| Plotting Information Cards | 23 |
| INPUT CHECKING AND PROGRAM PRINTOUT | 27 |
| COMPUTER REQUIREMENTS | 28 |
| INPUT/OUTPUT EXAMPLES | 31 |
| ACKNOWLEDGMENT | 36 |

## LIST OF FIGURES


| | | Page |
|---|---|---|
| Figure 1. | Geometry for Perspective Projection | 3 |
| Figure 2. | Geometry for Orthographic Projection | 6 |
| Figure 3. | Conversion to $x_s, y_s$ Coordinates | 7 |
| Figure 4. | General Surface Element | 8 |
| Figure 5. | Pressure Coefficient Quadrilateral System | 10 |
| Figure 6. | Hypothetical Pressure Coefficient Grid with Isobars | 11 |
| Figure 7. | Sectional Interface | 11 |
| Figure 8. | Correct Indexing of Lines in Right- and Left-Handed Coordinate Systems | 14 |
| Figure 9. | Example of a Section in Two Parts with a Hole in One Part | 15 |
| Figure 10. | Representation of a Submarine | 16 |
| Figure 11. | Sample Set of Streamlines | 22 |
| Figure 12. | Raster Coordinates | 28 |
| Figure 13. | ADP Off-Line Request | 29 |
| Figure 14. | Comparison of Perspective and Orthographic Projections | 32 |
| Figure 15. | Sphere with Off-Body Streamlines | 33 |
| Figure 16. | On-Body Streamlines on Helicopter Fuselage | 34 |
| Figure 17. | Isobar on Helicopter Rotor Hub Fairing | 35 |
| Figure 18. | Rotating Tank Pathline and Vortex Lines | 37 |


## LIST OF TABLES


| | | |
|---|---|---|
| Table 1. | Valid Parameter Combinations | 13 |
| Table 2. | ISTRM and IGRID Combinations | 25 |
| Table 3. | Compile, Load, and Go Control Cards | 30 |
| Table 4. | Input for On-Body Streamline Example | 34 |
| Table 5. | List of Running Times for Sample Problems | 36 |

## INTRODUCTION

XYZPLOT is a passive graphics program for displaying the results of potential flow calculations. It was written for the CDC 6000 series computers and the Stromberg-Carlson 4060 Stored Program Recording System. XYZPLOT was specifically programmed to mate with the input formats and restart files of the XYZ Potential Flow Program (XYZ PFP),[1] but with proper interfacing XYZPLOT may be used to display results from similar programs.

The body may be specified in surface element form as in XYZ PFP, or in an alternate form (outline form) in which the user specifies points which comprise an outline of the body. However, when plotting isobars or on-body streamlines, the surface element points must always be specified.

A Mach number correction is included for plotting isobars in the case of subsonic flow in air. A special version of the XYZ PFP has been developed to generate pressure coefficients for this case.*

XYZPLOT is intended to supersede two earlier programs, VIEWPLOT and ISOPLOT.[2] It has been successfully applied to several problems, including a study of isobars on helicopter rotor hubs and a comparison of the XYZ PFP with analytic results for an ellipsoid.

XYZPLOT and its interactive graphics counterpart, DESIGN,[3,†] represent the present graphics capability for the XYZ Potential Flow Program.

---

* Consult Code 1843, Numerical Fluid Dynamics Branch, for details.

† DESIGN presently has the capability to display and edit body points. Streamline and isobar routines will soon be added.

1 Dawson, Charles W. and Dean, Janet S., "The XYZ Potential Flow Program," Naval Ship Research and Development Center Report 3892 (June 1972).

2 Reingruber, John K., "Three-Dimensional Computer Graphics for Fluid Dynamics," Computation and Mathematics Department Technical Note CMD-56-72 (November 1972).

3 Kelly, Barbara M. and Marquardt, Mary Beth, "Interactive Helicopter Design: Geometry Package User's Manual," Computation and Mathematics Department, Departmental Report CMD-28-74 (September 1974).

## DESCRIPTION OF METHODS

### PROJECTION

XYZPLOT projects points in space onto a plotting plane, S, by one of two user selected methods. Both methods require the specification of an observation point, $Q_0 = (x_0, y_0, z_0)$, as well as two points, $Q_1 = (x_1, y_1, z_1)$ and $Q_2 = (x_2, y_2, z_2)$, which lie in the plotting plane. $Q_1$ is taken as the origin of the plotting plane coordinate system (designated by $x_s, y_s$), and $Q_2$ determines the positive $x_s$ direction. A point lying in the positive $y_s$ direction $Q_3 = (x_3, y_3, z_3)$ is calculated by finding the vector product of $\overrightarrow{Q_1Q_0}$ and $\overrightarrow{Q_1Q_2}$. No distortion will occur when $\overrightarrow{Q_1Q_0}$ is perpendicular to $\overrightarrow{Q_1Q_2}$.

#### Perspective Projection

The perspective projection $Q_p = (x_p, y_p, z_p)$ of a point in space $Q_g = (x_g, y_g, z_g)$ is *the intersection of the line-of-sight* ($\overrightarrow{Q_0Q_g}$) *with the* plotting plane. See Figure 1. This may be formulated as follows:

$$\overrightarrow{Q_pQ_g} \parallel \overrightarrow{Q_gQ_0} \qquad (1)$$

$$\overrightarrow{Q_1Q_p} \perp \overrightarrow{Q_1Q_0} \qquad (2)$$

Constraint (1) is satisfied if

$$\overrightarrow{Q_pQ_g} = t(\overrightarrow{Q_0Q_g}) \qquad (-\infty < t < \infty)$$

In Cartesian coordinates,

$$x_g - x_p = t(x_0 - x_g)$$

$$y_g - y_p = t(y_0 - y_g)$$

$$z_g - z_p = t(z_0 - z_g)$$

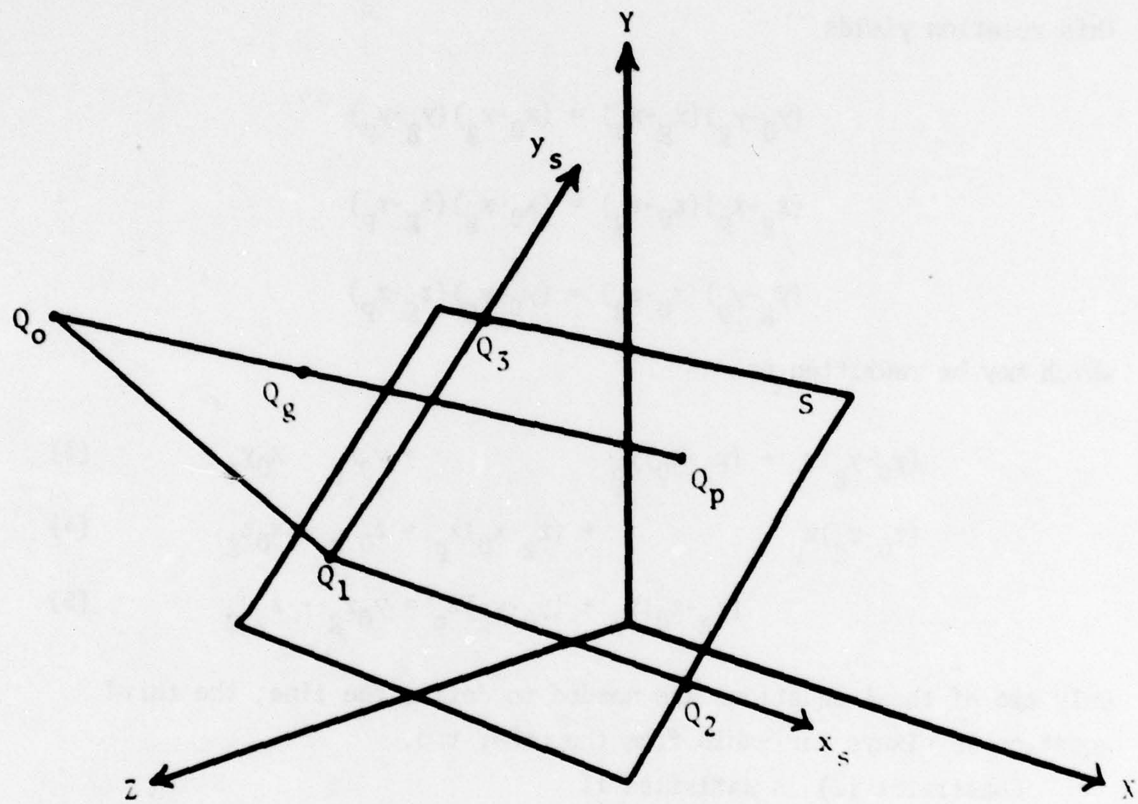



Figure 1. Geometry for Perspective Projection

The plotting plane, S, contains points $Q_1$,$Q_2$, and $Q_3$, which define $x_s$,$y_s$ coordinate system. The observation point $Q_o$ and a point in space $Q_g$ determine the line-of-sight. The projected point $Q_p$ lies at the intersection of the plotting plane with the line-of-sight.

or

$$t = \frac{x_g - x_p}{x_0 - x_g} = \frac{y_g - y_p}{y_0 - y_g} = \frac{z_g - z_p}{z_0 - z_g}$$

This relation yields

$$(y_0 - y_g)(x_g - x_p) = (x_0 - x_g)(y_g - y_p)$$

$$(x_g - x_p)(z_0 - z_g) = (x_0 - x_g)(z_g - z_p)$$

$$(y_g - y_p)(z_0 - z_g) = (y_0 - y_g)(z_g - z_p)$$

which may be rewritten as

$$(y_0 - y_g)x_p + (x_g - x_0)y_p = y_0 x_g - x_0 y_g \tag{3}$$

$$(z_0 - z_g)x_p + (x_g - x_0)z_p = z_0 x_g - x_0 z_g \tag{4}$$

$$(z_g - z_0)y_p + (y_0 - y_g)z_p = y_0 z_g - z_0 y_g \tag{5}$$

Only two of these equations are needed to define the line; the third equation is always derivable from the other two.

Constraint (2) is satisfied if

$$\overrightarrow{Q_1 Q_p} \cdot \overrightarrow{Q_1 Q_0} = 0$$

In Cartesian coordinates,

$$(x_p - x_1)(x_0 - x_1) + (y_p - y_1)(y_0 - y_1) + (z_p - z_1)(z_0 - z_1) = 0$$

or

$$\begin{aligned}(x_0 - x_1)x_p + (y_0 - y_1)y_p + (z_0 - z_1)z_p = (x_0 - x_1)x_1 \\ + (y_0 - y_1)y_1 + (z_0 - z_1)z_1\end{aligned} \tag{6}$$

Equation (6) along with two equations selected from equations (3), (4), and (5) constitute a system of three equations in the three unknowns $x_p$, $y_p$, and $z_p$. The system will have a solution provided $Q_0$

is distinct from $Q_g$ and $\overrightarrow{Q_0Q_g}$ is not parallel to the plane S.

Orthographic Projection

The orthographic projection $Q_p = (x_p, y_p, z_p)$ of a point in space $Q_g = (x_g, y_g, z_g)$ is the projection of $Q_g$ onto the plotting plane along a line normal to the plane. See Figure 2. This may be formulated as

$$\overrightarrow{Q_pQ_g} \cdot \overrightarrow{Q_1Q_2} = 0$$

$$\overrightarrow{Q_pQ_g} \cdot \overrightarrow{Q_1Q_3} = 0$$

$$\overrightarrow{Q_1Q_p} \cdot \overrightarrow{Q_1Q_0} = 0$$

(for orthographic projection $\overrightarrow{Q_0Q_1}$ is taken as normal to S).

In Cartesian coordinates,

$$(x_g-x_p)(x_2-x_1) + (y_g-y_p)(y_2-y_1) + (x_g-z_p)(z_2-z_1) = 0$$

$$(x_g-x_p)(x_3-x_1) + (y_g-y_p)(y_3-y_1) + (z_g-z_p)(z_3-z_1) = 0$$

$$(x_p-x_1)(x_0-x_1) + (y_p-y_1)(y_0-y_1) + (z_p-z_1)(z_0-z_1) = 0$$

which may be rewritten as

$$(x_2-x_1)x_p+(y_2-y_1)y_p+(z_2-z_1)z_p = (x_2-x_1)x_g+(y_2-y_1)y_g+(z_2-z_1)z_g$$

$$(x_3-x_1)x_p+(y_3-y_1)y_p+(z_3-z_1)z_p = (x_3-x_1)x_g+(y_3-y_1)y_g+(z_3-z_1)z_g$$

$$(x_0-x_1)x_p+(y_0-y_1)y_p+(z_0-z_1)z_p = (x_0-x_1)x_1+(y_0-y_1)y_1+(z_0-z_1)z_1$$

or

$$\begin{pmatrix} (x_2-x_1) & (y_2-y_1) & (z_2-z_1) \\ (x_3-x_1) & (y_3-y_1) & (z_3-z_1) \\ (x_0-x_1) & (y_0-y_1) & (z_0-z_1) \end{pmatrix} \begin{pmatrix} x_p \\ y_p \\ z_p \end{pmatrix} \begin{matrix} = \\ = \\ = \end{matrix} \begin{pmatrix} (x_2-x_1)x_g+(y_2-y_1)y_g+(z_2-z_1)z_g \\ (x_3-x_1)x_g+(y_3-y_1)y_g+(z_3-z_1)z_g \\ (x_0-x_1)x_1+(y_0-y_1)y_1+(z_0-z_1)z_1 \end{pmatrix}$$

This system of linear equations has no solution if the coefficient matrix is singular, i.e., when $\overrightarrow{Q_2Q_1} \cdot (\overrightarrow{Q_3Q_1} \times \overrightarrow{Q_0Q_1}) = 0$. There is no danger of this happening as long as $\overrightarrow{Q_1Q_0}$ is nearly normal to S.

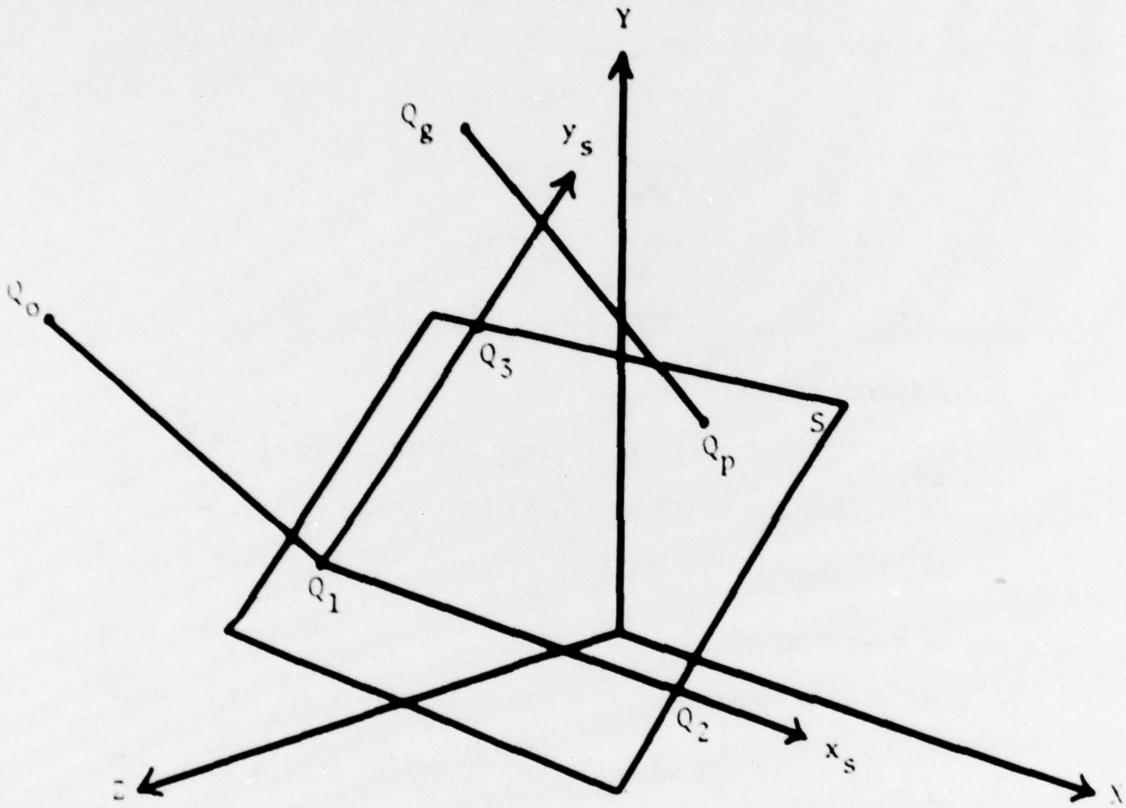



Figure 2. Geometry for Orthographic Projection

The plotting plane, S, contains points $Q_1$,$Q_2$, and $Q_3$ which define the $x_s$,$y_s$ coordinate system. The observation point $Q_o$ is no al to S at $Q_1$. A point in space $Q_g$ is projected along a line normal to S. The projected point $Q_p$ lies at the intersection of this normal with S.

### Conversion to $x_s, y_s$ Coordinates

Once the three coordinates of the projected point $Q_p$ are determined (by either projection method) it is necessary to find the corresponding coordinates in the $x_s, y_s$ coordinate system. This is done by taking the scalar product of the position vector in the $x_s, y_s$ system ($\overrightarrow{Q_1Q_p}$) with the respective base vectors $\hat{x}_s = \overrightarrow{Q_1Q_2}$ and $\hat{y}_s = \overrightarrow{Q_1Q_3}$. $Q_3$ is chosen so that $|\hat{x}_s| = |\hat{y}_s|$. The coordinates are then normalized by dividing by R, where $R = |\hat{x}_s| = |\hat{y}_s|$.

$$x_{p_s} = \frac{\overrightarrow{Q_1Q_p} \cdot \overrightarrow{Q_1Q_2}}{R}$$

$$y_{p_s} = \frac{\overrightarrow{Q_1Q_p} \cdot \overrightarrow{Q_1Q_3}}{R}$$

See Figure 3.

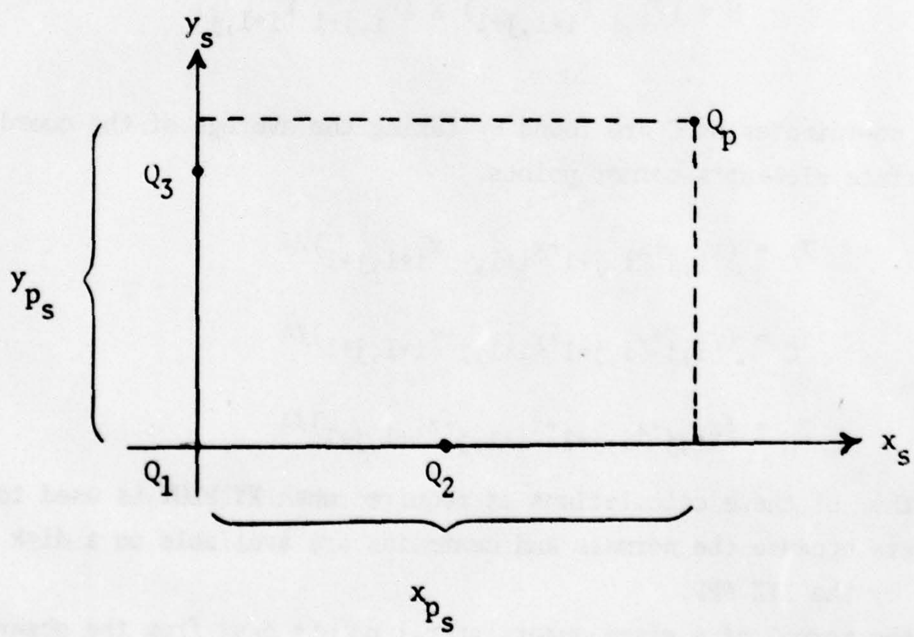



Figure 3. Conversion to $x_s, y_s$ Coordinates

## LOCATING HIDDEN SURFACE ELEMENTS

Associated with each surface element is a normal $\vec{N}$ specified at the geometric center C of the element. $\vec{N}$ is defined by the vector product of the diagonals of the surface element. See Figure 4.

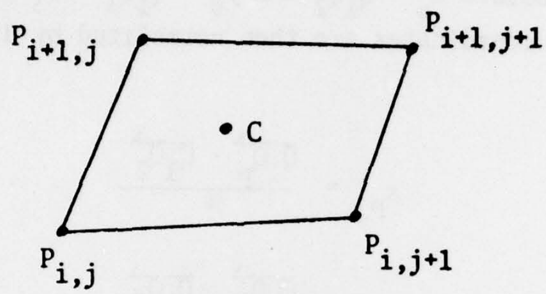



Figure 4. General Surface Element

$$N = (\overrightarrow{P_{i,j}\ P_{i+1,j+1}}) \times (\overrightarrow{P_{i,j+1}\ P_{i+1,j}})$$

The coordinates of C are found by taking the average of the coordinates of the surface element's corner points.

$$X_C = (x_{i,j}+x_{i,j+1}+x_{i+1,j}+x_{i+1,j+1})/4$$

$$Y_C = (y_{i,j}+y_{i,j+1}+y_{i+1,j}+y_{i+1,j+1})/4$$

$$Z_C = (z_{i,j}+z_{i,j+1}+z_{i+1,j}+z_{i+1,j+1})/4$$

Neither of these calculations is required when XYZPLOT is used to plot isobars because the normals and centroids are available on a disk file generated by the XYZ PFP.

If the normal of a given quadrilateral points away from the observer, it is considered hidden. This is determined by finding the scalar product of the normal with the vector indicating the direction of the observer, $\vec{D}$.

$$SP = \vec{N} \cdot \vec{D}$$

During perspective projection $\vec{D}$ is the vector from the observation point to the center of the surface element. During orthographic projection $\vec{D}$ is the normal to the plotting plane. If SP>0, the element is hidden and therefore not plotted. This method does not detect surfaces which are hidden due to blockage.

## DETERMINING HIDDEN STREAMLINES

Hidden off-body streamlines are determined as follows: The user specifies a plane by its origin and a normal which points toward the observer. Any streamline segment having an endpoint which is not on the observer side of the plane is not plotted. This leaves the user the option of selecting which streamlines will be plotted in each view.

XYZPLOT automatically suppresses on-body streamlines which lie on hidden surface elements.

## PLOTTING ISOBARS

### Determining Pressure Coefficients

The local velocities (at the null points) are calculated from a given onset velocity ($V_{\infty_x}$, $V_{\infty_y}$, $V_{\infty_z}$) and the local velocities for the X, Y, and Z flows ($(VX1,VY1,VZ1)_i$, $(VX2,VY2,VZ2)_i$, $(VX3,VY3,VZ3)_i$). The local velocities for the X, Y, and Z flows are written on TAPE03 by section 4 of the XYZ PFP. At each null point, i, the local velocities are

$$\begin{pmatrix} VX_i \\ VY_i \\ VZ_i \end{pmatrix} = \begin{pmatrix} VX1_i & VX2_i & VX3_i \\ VY1_i & VY2_i & VY3_i \\ VZ1_i & VZ2_i & VZ3_i \end{pmatrix} \begin{pmatrix} V_{\infty_x} \\ V_{\infty_y} \\ V_{\infty_z} \end{pmatrix}$$

From these local velocities, the pressure coefficients at each null point are then calculated. For incompressible flow

$$C_{P_i} = 1 - \frac{VX_i^2 + VY_i^2 + VZ_i^2}{V_{\infty_x}^2 + V_{\infty_y}^2 + V_{\infty_z}^2} \qquad (7)$$

If the compressible flow version of the XYZ PFP was used, a Mach number correction is applied

$$C_{P_i} = \frac{\left[1 + .2M^2\left(1 - \dfrac{VX_i^2 + VY_i^2 + VZ_i^2}{V_{\infty_x}^2 + V_{\infty_y}^2 + V_{\infty_z}^2}\right)\right]^{3.5} - 1}{.7M^2} \tag{8}$$

Locating Isobars

Associated with each null point is a pressure coefficient (computed from either Equation 7 or Equation 8). The set of null points (and therefore the set of pressure coefficients) form a system of quadrilaterals. This system is shown as broken lines on the body section in Figure 5.

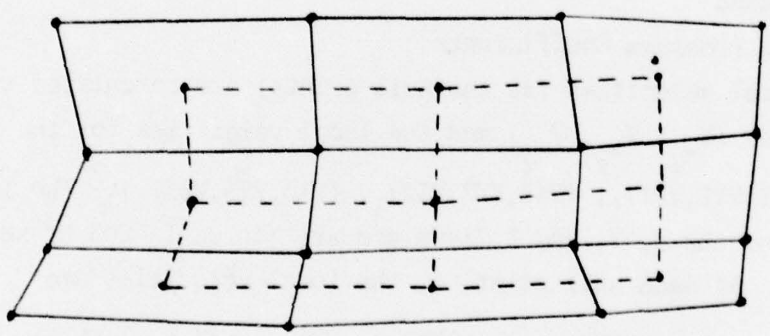


Figure 5. Pressure Coefficient Quadrilateral System

A specified isobar ($C_{P_s}$) is located by searching over the vertices of each of these quadrilaterals to find cases where the corner values bracket $C_{P_s}$. Once found, linear interpolation will yield at least two points on that quadrilateral having approximately the specified pressure coefficient. These points are connected to form an isobar segment. If more than two points along the quadrilateral's edge are found to have the same pressure coefficient, the pairs having the smallest combined lengths are arbitrarily connected. See Figure 6.

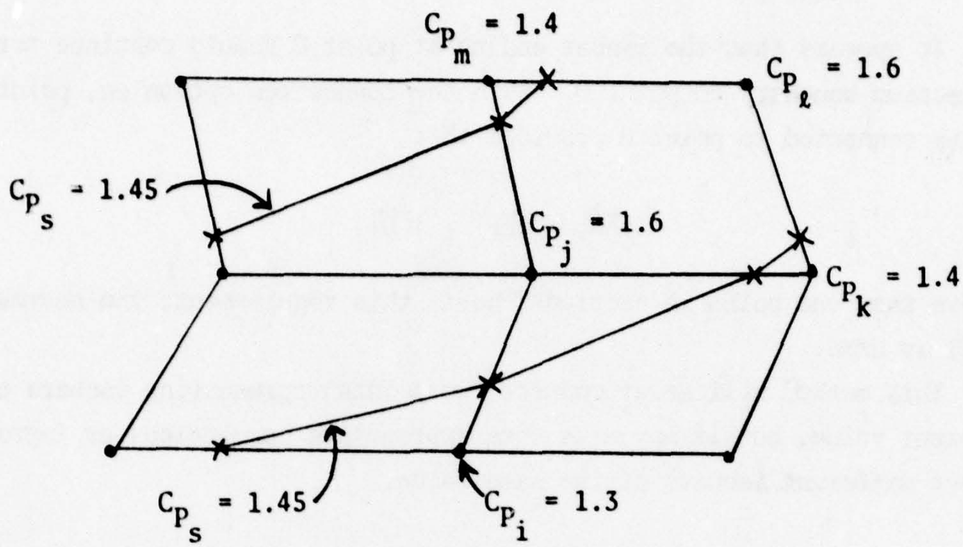



Figure 6. Hypothetical Pressure Coefficient Grid with Isobars

The scheme used to index the surface elements (and null points) does not carry across section boundaries, therefore preventing isobars from being drawn between two sections. A simple option is available to the user which often circumvents this problem. Consider the situation represented in Figure 7.

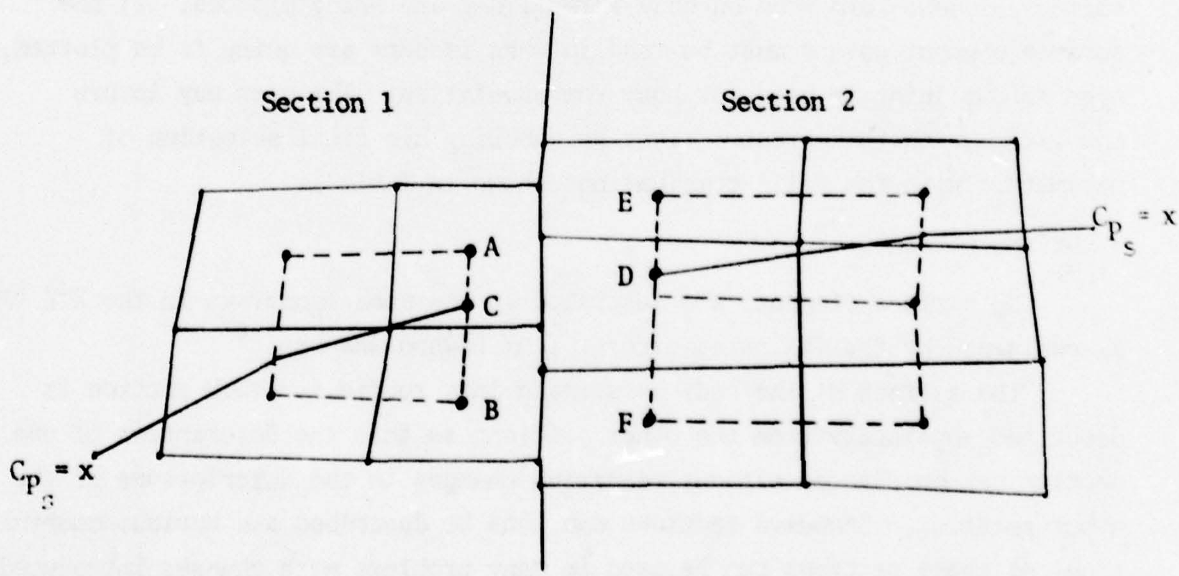



Figure 7. Sectional Interface

It appears that the isobar ending at point C should continue across the section boundary to point D. With the connection option on, point B will be connected to point E provided that

$$|\overrightarrow{AB}| + |\overrightarrow{EF}| \geq |\overrightarrow{CD}|$$

If more than one point in section 2 meets this requirement, the nearest point (to C) is used.

This method will never connect two points representing isobars of different value, but it may miss some appropriate connections or improperly connect different isobars of the same value.

## PREPARATION OF INPUT

### BODY DESCRIPTION

XYZPLOT will plot a body specified by either surface elements or line segments. However the following restrictions arise whenever on-body streamlines or isobars are to be plotted: 1) the body must be plotted in surface element form when on-body streamlines are being plotted; 2) the surface element points must be read in when isobars are going to be plotted, even if outlining is used for body representation. The user may insure compliance with these restrictions by checking his final selection of parameters with the valid combinations shown in Table 1.

#### Surface Elements

The surface elements are described in the same manner as in the XYZ PFP, as explained by the following excerpt from Dawson and Dean.[4]

"The surface of the body is divided into sections. Each section is described separately from the other sections so that the description of one section can be changed without requiring changes in the descriptions of the other sections. Standard sections can thus be described and various combinations of these sections can be used in many problems with changes introduced as needed.

---

[4] Dawson and Dean, op.cit., pp. 30-33.

TABLE 1 - VALID PARAMETER COMBINATIONS

| Combination | ITYPE | ISE | IOL | IBODY | ISTRM |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 4,5 | 2 | 0 |
| 2 | 0 | 2,5 | 0 | 1 | 0 |
| 3 | 0 | 2,5 | 4,5 | 1,2 | 0 |
| 4 | 1 | 0 | 4,5 | 2 | 0,1,2 |
| 5 | 1 | 2,5 | 0 | 1 | 0,1,2 |
| 6 | 1 | 2,5 | 4,5 | 1,2 | 0,1,2 |
| 7 | 2 | 0 | 4,5 | 2 | 0 |
| 8 | 2 | 2,5 | 0 | 1 | 0,1,2 |
| 9 | 2 | 2,5 | 4,5 | 1 | 0,1,2 |
| 10 | 2 | 2,5 | 4,5 | 2 | 0 |
| 11 | 3 | 0 | 4,5 | 2 | 0 |
| 12 | 3 | 2,5 | 0 | 1 | 0,1,2 |
| 13 | 3 | 2,5 | 4,5 | 1,2 | 0,1,2 |

"Each section is subdivided by two sets of lines, more or less at right angles to each other. The input consists of the X, Y, and Z coordinates of the points at the intersection of the lines and the indices N, M to indicate the lines. The indices for the lines should be chosen so that when viewed from outside the body, N increases to the right when M increases toward the top. Any rotation of this arrangement is also permitted but a reflection will result in an inward pointing normal vector. Of course, if a left-handed coordinate system is being used, N and M must be interchanged... . [See Figures 8, 9, and 10.]

"The plane quadrilaterals which make up the approximation to the surface are generated from the point data. A quadrilateral will be generated only when the four corner points N,M; N,M+1; N+1,M+1; and N+1,M are given. Thus, a section with a hole in it or a section with two parts can be specified. The advantage of this arrangement is that part of a body can be changed or more accurately represented without requiring that all the points be renumbered."

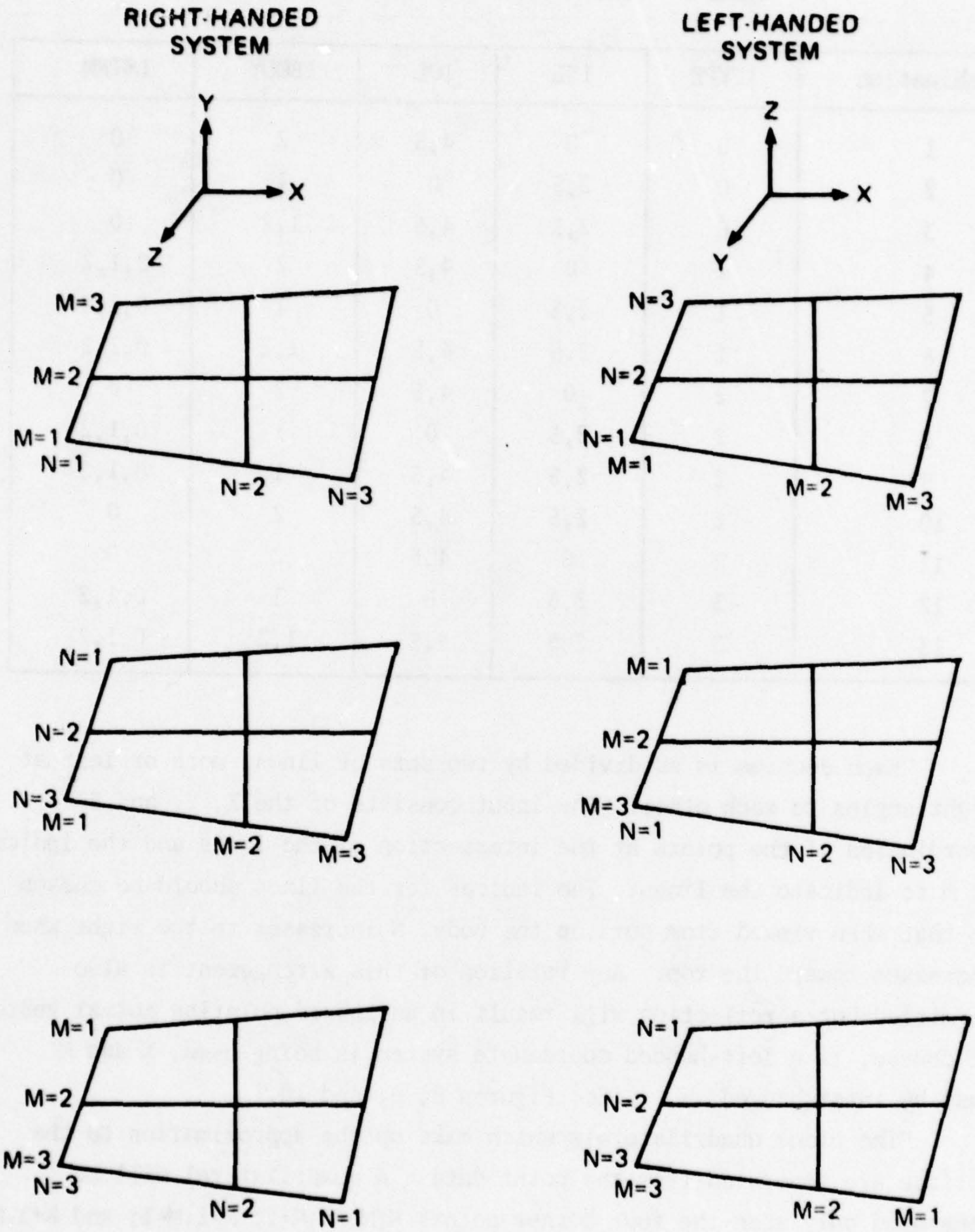



**Figure 8 – Correct Indexing of Lines in Right- and Left-Handed Coordinate Systems**

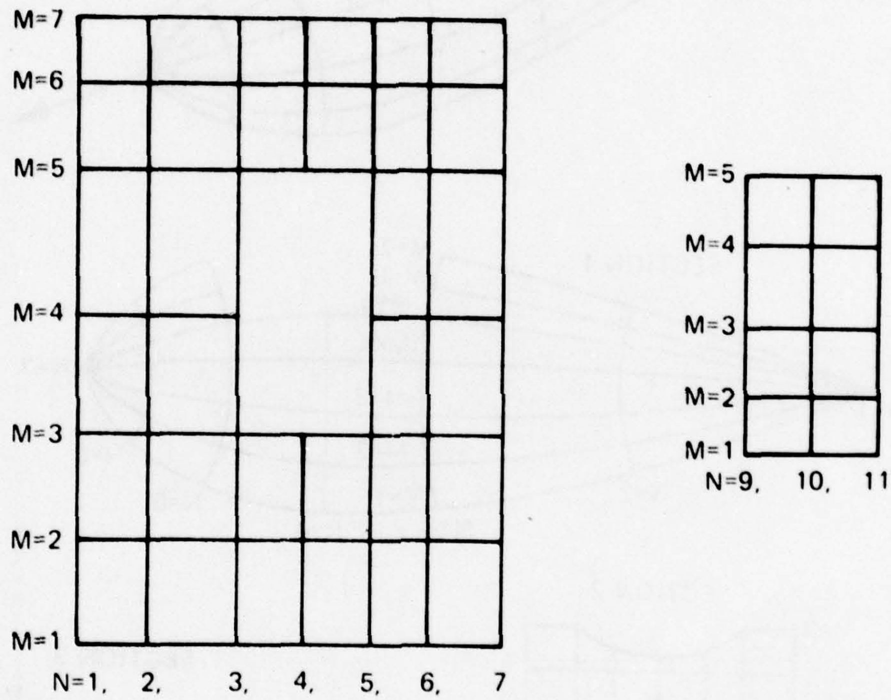



Figure 9 – Example of a Section in Two Parts with a Hole in One Part

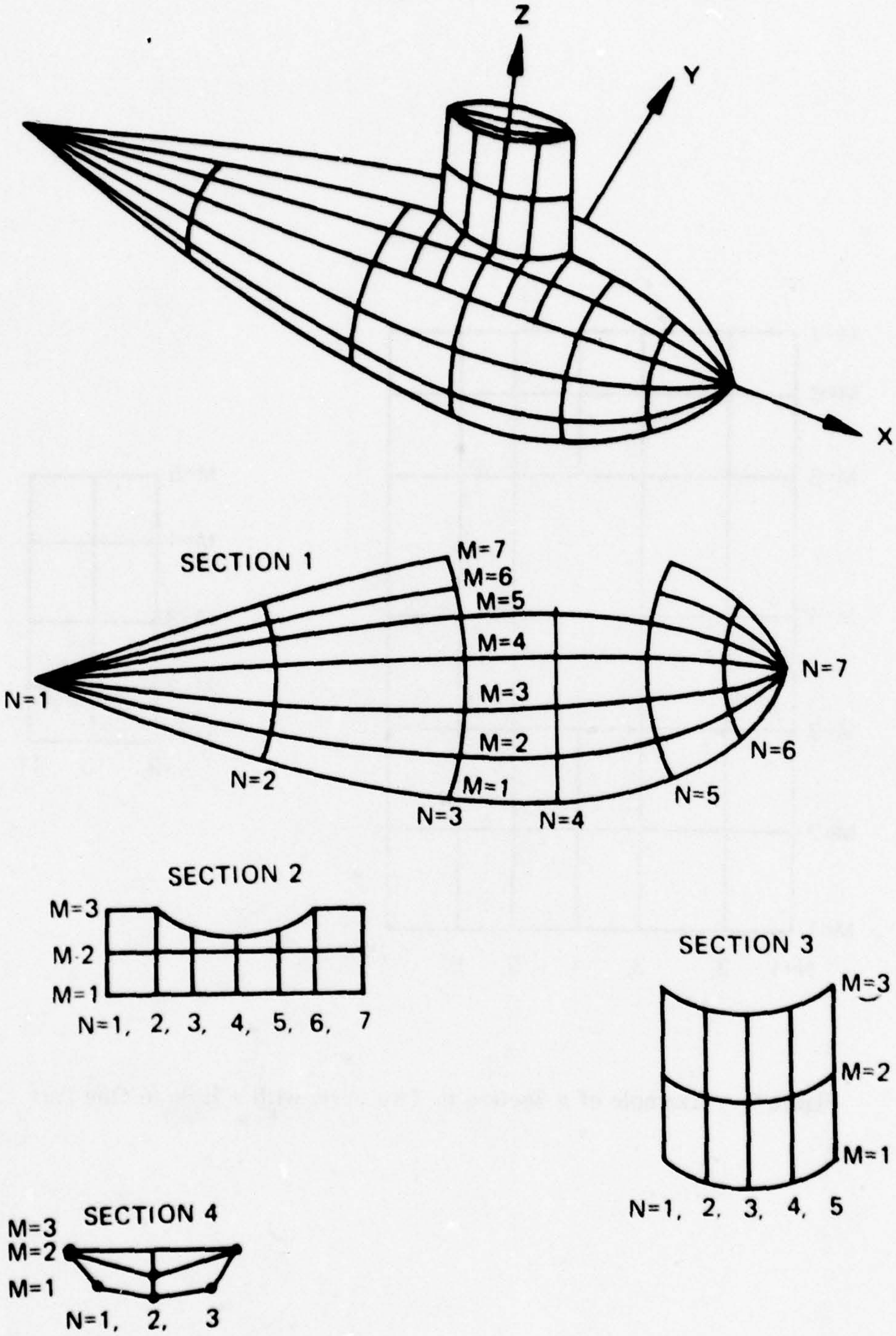



**Figure 10 – Representation of a Submarine**

Outline

The body outline is divided into components, and each component is composed of line segments. The line segments are specified by two consecutively indexed points. To plot the outline, a line is drawn from the point indexed M to the point indexed M+1 within a component. To make a component close on itself, the point with the largest index must be identical to the point with the smallest index.

DATA ORGANIZATION AND FORMAT

XYZPLOT uses a combination of cards, disk files, and tapes as input. It requires a problem identification card, a control parameter card, body point cards, and a user identification card. The body point cards may be punched cards, or card images which reside on a disk or tape file. Each view then requires a set of plotting information cards followed by an end-of-record card. Streamline or isobar data are read from a disk or tape file.

Problem Identification and Control Parameters

The problem identification card is first in the data deck and is in FORTRAN format (6A10). The information in this card should be approximately centered between columns 2 and 60. The control parameter card is next and is in format (8I5, F5.3). All parameters must be right-justified, as blanks are interpreted as zeros. This card must contain the following information:

| PARAMETER | COLUMN | | DESCRIPTION |
|---|---|---|---|
| NVIEWS | 1-5 | | Number of views to be generated. |
| ISE | 10 | | Surface element tape indicator. |
| | | ISE | SITUATION |
| | | 0 | If not reading surface elements. |
| | | 2 | If reading from disk file or tape (attach as TAPE2). |
| | | 5 | If reading from cards. |

| PARAMETER | COLUMN | | DESCRIPTION |
|---|---|---|---|
| IOL | 15 | | Outline tape indicator. |
| | | IOL | SITUATION |
| | | 0 | If not reading outline points. |
| | | 4 | If reading from disk file or tape (attach as TAPE4). |
| | | 5 | If reading from cards. |
| ITYPE | 20 | | Flow data type indicator. |
| | | ITYPE | SITUATION |
| | | 0 | No data (only body may be plotted). |
| | | 1 | Off-body streamline points (e.g. TAPE16 from section 6 of XYZ PFP). |
| | | 2 | On-body streamline points (e.g. TAPE17 from section 7 of XYZ PFP). |
| | | 3 | Isobar Information (e.g. TAPE03 from section 4 of XYZ PFP). |
| ISYS | 25 | | Coordinate System orientation indicator. |
| | | ISYS | SITUATION |
| | | -1 | Left-handed. |
| | | 1 | Right-handed. |
| IVERS | 30 | | Version of XYZ PFP used. |
| IOUT | 35 | | Set IOUT=1 to prevent input echo-checking. |
| NQE | 36-40 | | Number of surface elements. (Set NQE=0 if not reading surface element points). |
| XMAC | 41-45 | | Mach number. Set XMAC=0 unless compressible flow version of XYZ PFP was used. |

Body Point Cards

It is possible to have the body plotted in surface element form in some views and in outline form in other views during a given computer run. To do this, surface element points and outline points must both be read in (in that order). The user must be careful to specify the proper values for ISE and IOL on the control parameter card.

Surface Element Points. If the body is to be plotted in surface element form in any view, or if isobars or on-body streamlines will be plotted in any view, the surface element point cards must be next in the data deck. These cards are the same as the body point cards for the XYZ PFP, except that the last parameter on each card (the normal component of the velocity at the body surface) is not required. The format for these cards is (3F12.9, 4I4). The maximum number of body sections allowed is 25, the maximum number of body points allowed in a body section is 726, and the entire body may consist of up to 650 surface elements. Each point card must contain the following information:

| PARAMETER | COLUMN | DESCRIPTION |
|---|---|---|
| XI | 1-12 | X-coordinate of the point. |
| YI | 13-24 | Y-coordinate of the point. |
| ZI | 25-36 | Z-coordinate of the point. |
| NI | 39-40 | N-index of the point ($1 \leq NI \leq 70$). |
| MI | 43-44 | M-index of the point ($1 \leq MI \leq 40$). |
| NS | 45-48 | Section identification number ($1 \leq NS \leq 9999$). NS must be unique for each section. |
| NE | 52 | Change indicator for the direction of the normal vector. When NE on the first card of a section is not blank or zero, NI and MI are interchanged for that section to change the direction of the normal vector. NE is ignored on the other cards. |

All point cards in a section must be placed together, but they may be in any order within the section. A blank card or an end-of-record must follow the last section.

If the surface element points are to be read in from a disk file or tape, the data file must be attached as TAPE2.

Outline Point Cards. If the body is to be plotted in outline form in any view, the outline point cards must be next in the data deck. The format for the outline cards is (3F12.9, 2I4). The maximum number of outline points allowed in a body component is 100, and the body may consist of up to 25 components. Each point card must contain the following information:

| PARAMETER | COLUMN | DESCRIPTION |
|---|---|---|
| XI | 1-12 | X-coordinate of the point. |
| YI | 13-24 | Y-coordinate of the point. |
| ZI | 25-36 | Z-coordinate of the point. |
| MI | 39-40 | Index of the point ($MI \le 100$). |
| NC | 41-44 | Component identification number ($1 \le NC \le 9999$). NC must be unique for each component. |

All point cards for a component must be placed together, but they may be in any order within the component. A blank card or an end-of-record must be placed after the last component.

If the body outline points are to be read from a disk file or tape, the data file must be attached as TAPE4.

Streamline Points and Isobar Data

During a given computer run XYZPLOT can plot either on-body streamlines, off-body streamlines, or isobars. The user must be careful that the type of data file attached (as TAPE50) agrees with the value of ITYPE on the control parameter card. The files must be written unformatted as follows (all variable types are standard FORTRAN default):

Off-Body Streamline Points. Each set of off-body streamlines requires one record with the following parameters:

| PARAMETER | DESCRIPTION |
|---|---|
| NOBP | Number of off-body streamlines in the set ($NOBP \le 726$). |
| NST | Number of time steps in this set. |
| IEND | Indicator that signals the last set of streamlines: IEND=0 when another set follows; IEND=1 to signal the last set. |
| VX<br>VY<br>VZ | X, Y, and Z components of the onset velocity for this set. |

The streamline points are contained in the next NST+1 records. This pattern continues until all the streamline sets are on the file. As indicated above, the last set is flagged by IEND=1.

The following example shows how the file would be written for the sample set of streamlines in Figure 11. Streamlines formed by negative time steps are treated as a separate set from those formed by positive time steps, even though they may have the same step 0 starting points.

| Record #1 | Record #2 |
|---|---|
| NOBP,NST,IEND,VX,VY,VZ For First Set | (For Positive Time Steps) $[X,Y,Z]_{A-0},\cdots[X,Y,Z]_{E-0}$, |

| Record #3 | Record #4 | |
|---|---|---|
| $[X,Y,Z]_{A-1},\cdots,[X,Y,Z]_{E-1}$ | $[X,Y,Z]_{A-2},\cdots,[X,Y,Z]_{E-2}$ | |

| Record #5 | Record #6 |
|---|---|
| NOBP,NST,IEND,VX,VY,VZ For Second Set | (For Negative Time Steps) $[X,Y,Z]_{A-0},\cdots,[X,Y,Z]_{E-0}$, |

| Record #7 | Record #8 | |
|---|---|---|
| $[X,Y,Z]_{A-1},\cdots,[X,Y,Z]_{E-1}$ | $[X,Y,Z]_{A-2},\cdots,[X,Y,Z]_{E-2}$ | |

| |
|---|
| END OF FILE |

This file may contain streamline sets for several onset flows: in a given view XYZPLOT will search for and plot all off-body streamlines available for a specified onset flow.

This file is automatically written as TAPE16 by section 6 of XYZ PFP.

<u>On-Body Streamline Points.</u> Each set of on-body streamlines requires one record with the following parameters:

| PARAMETER | DESCRIPTION |
|---|---|
| NLIN | Number of streamlines in the set. |
| VX<br>VY<br>VZ | X, Y, and Z components of the onset velocity for the set. |

This record is followed by NLIN records which contain the streamline points

These records are organized as follows:

NSLP,(X(I),Y(I),Z(I),NQUAD(I),I=1,NSLP)

where NSLP is the number of streamline points; X, Y, and Z are their coordinates; and NQUAD is the number of the surface element on which the point lies.

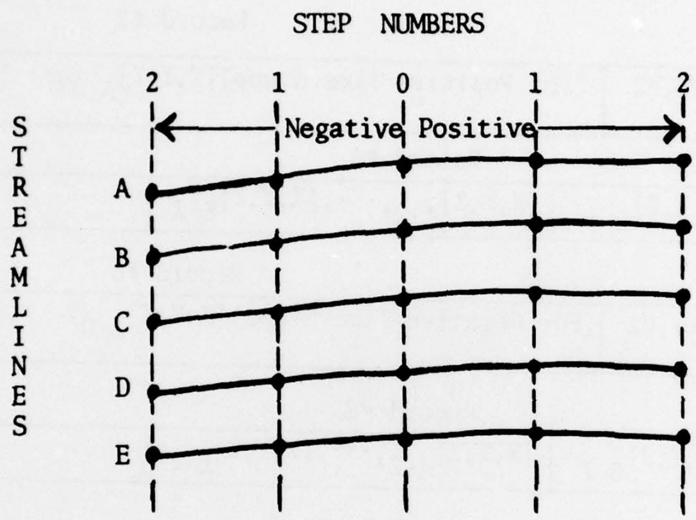



Figure 11. Sample Set of Streamlines

The following example shows how the file would be written for the sample set of streamlines in Figure 11. For this example streamlines formed by negative time steps are treated as a separate set from those formed by positive time steps.

| Record #1 | Record #2 |
|---|---|
| NLIN,VX,VY,VZ for first set | NSLP, $[X,Y,Z,NQUAD]^{+}_{A-0}$, $[X,Y,Z,NQUAD]^{+}_{A-1}$, $[X,Y,Z,NQUAD]^{+}_{A-2}$ |

| Record #3 |
|---|
| NSLP, $[X,Y,Z,NQUAD]^{+}_{B-0}$, $[X,Y,Z,NQUAD]^{+}_{B-1}$, $[X,Y,Z,NQUAD]^{+}_{B-2}$ |

| Records #4-6 | Record #7 |
|---|---|
| ---------------------------------------- $[X,Y,Z,NQUAD]^{+}_{E-2}$ | NLIN,VX,VY,VZ for second set |

Record #8

| $[X,Y,Z,NQUAD]^{-}_{A-0}$ , $[X,Y,Z,NQUAD]^{-}_{A-1}$ , $[X,Y,Z,NQUAD]^{-}_{A-2}$ |
|---|

Records #9-12

| --------------------$[X,Y,Z,NQUAD]^{-}_{E-2}$ | END OF FILE |
|---|---|

This file may contain streamline sets for several onset flows: in a given view XYZPLOT will search for and plot all on-body streamlines available for a specified onset flow.

This file is automatically written as TAPE17 by section 7 of XYZ PFP.

Isobar Data. To locate and plot isobars, XYZPLOT requires the local velocities at the null points for the X, Y, and Z flows. These are read from TAPE03 of section 4 of the XYZ PFP.

User Identification Card

The next card is the user identification card. It is in format (3A10) and must have the following information:

| PARAMETER | COLUMN | DESCRIPTION |
|---|---|---|
| NAME | 1-10 | User's last name. |
| CODE | 11-20 | User's code. |
| PHONE | 21-30 | User's phone number. |

Plotting Information Cards

The plotting information cards are next, and must be provided for each view. Each set must be followed by a 7/8/9 (end-of-record) card. The first six plotting information cards are in format (6A10/4I5/3(3F20.7/),5F15.7). They contain the following information in the given order:

| PARAMETER | CARD/COLUMNS | DESCRIPTION |
|---|---|---|
| TITLE | 1/2-60 | Alphanumeric field containing the title to be displayed on the frame. |
| IBODY | 2/5 | Body plotting indicator. |

| IBODY | SITUATION |
|---|---|
| 1 | Body will be plotted in surface element form. |

| PARAMETER | CARD/COLUMNS | | DESCRIPTION |
|---|---|---|---|
| | | IBODY (cont.) | SITUATION |
| | | 2 | Body will be plotted in outline form. |
| ISTRM | 2/10 | | Streamline/Isobar indicator. |
| | | ISTRM | SITUATION |
| | | 0 | Plot no streamlines or isobars. |
| | | 1 | Plot streamlines or isobars. |
| | | 2 | Advance frame, then plot streamlines or isobars. |
| IGRID | 2/15 | | Grid Indicator. |
| | | IGRID | SITUATION |
| | | 0 | No grid. |
| | | 1 | Grid displayed. |
| | | 2 | Advance frame; then draw grid. |
| IMODE | 2/20 | | Mode Indicator. |
| | | IMODE | MODE |
| | | 0 | Perspective |
| | | 1 | Orthographic |
| XØ<br>YØ<br>ZØ | 3/1-20<br>3/21-40<br>3/41-60 | | Coordinates of the observation point. |
| X1<br>Y1<br>Z1 | 4/1-20<br>4/21-40<br>4/41-60 | | Coordinates of the plotting plane origin. |
| X2<br>Y2<br>Z2 | 5/1-20<br>5/21-40<br>5/41-60 | | Coordinates of a point along the $x_s$-axis of the plotting plane. |
| XL<br>XR<br>XB<br>XT | 6/1-15<br>6/16-30<br>6/31-45<br>6/46-60 | | Values in the $x_s$-$y_s$ coordinate system of the left, right, bottom, and top margins, respectively, of the plotting frame. If not specified, these quantities will be computed according to the value of SR below. |

| PARAMETER | CARD/COLUMNS | DESCRIPTION |
|---|---|---|
| SR | 6/61-70 | Size ratio which governs the size of the picture. |

| SR | SIZE |
|---|---|
| 1.0 | Full size |
| 0 < SR < 1.0 | Fraction of full size, (e.g., if SR=.5, then the picture will be scaled to half-size). |
| 0.0 | XL, XR, YB, YT are specified above. |

IGRID allows the user to select a rectangular grid to appear on one of the output frames. The grid spacing is approximately 7 millimeters. The parameters ISTRM and IGRID permit each view to occupy up to three frames of output. Table 2 may be used to predict the output resulting from various combinations of ISTRM and IGRID.

TABLE 2 - ISTRM AND IGRID COMBINATIONS

| IF ISTRM = | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|---|---|---|
| AND IGRID = | 0 | 1 | 2 | 0 | 1 | 2 | 0 | 1 | 2 |
| The body appears in frame | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| The streamlines or isobars appear in frame | | | | 1 | 1 | 1 | 2 | 2 | 3 |
| The grid appears in frame | | 1 | 2 | | 1 | 2 | | 1 | 2 |

The seventh plotting information card is in format (2I5) and requires the following information:

| PARAMETER | COLUMN | DESCRIPTION |
|---|---|---|
| NSP (NCP) | 4-5 | Number of body sections (components) to be plotted. NSP (NCP) $\leq$ 25. |
| ISM | 10 | Number of planes of symmetry |

| ISM | SYMMETRY PLANES |
|---|---|
| 0 | None |
| 1 | Y = 0 |
| 2 | Y = 0 and Z = 0 |
| 3 | Y = 0, Z = 0, and X = 0 |

This is followed with the following card(s) in format (16I5):

| PARAMETER | DESCRIPTION |
|---|---|
| NSN | Array that contains the section (component) numbers of the sections (components) to be plotted. The dimension of this array is 25. |

When plotting isobars or streamlines, the following cards must be included when applicable.

The ONSET FLOW card contains the onset velocity components for this view in format (3F12.5). This card is required for on- and off-body streamlines as well as isobars.

ON-BODY STREAMLINES require no further information.

OFF-BODY STREAMLINES require the following card in format (6F12.5):

| PARAMETER | COLUMN | DESCRIPTION |
|---|---|---|
| X1 | 1-12 | X-coordinate of the dividing plane origin. |
| Y1 | 13-24 | Y-coordinate of the dividing plane origin. |
| Z1 | 25-36 | Z-coordinate of the dividing plane origin. |
| XN | 37-48 | X-component of the normal vector of the dividing plane. |
| YN | 49-60 | Y-component of the normal vector of the dividing plane. |
| ZN | 61-72 | Z-component of the normal vector of the dividing plane. |

Set (XN,YN,ZN) = (0.0,0.0,0.0) or leave blank if all parts of all streamlines are to be plotted.

ISOBARS require the following cards. The first is in format (3I5):

| PARAMETER | COLUMN | DESCRIPTION |
|---|---|---|
| NSP | 4-5 | Number of body sections on which isobars are to be plotted. (NSP $\leq$ 25) |
| NCPG | 9-10 | Number of isobars to be plotted. (NCPG $\leq$ 25) |
| LIM | 15 | If LIM $\neq$ 0, isobars will be connected across section boundaries. Set LIM=0 or leave blank to suppress this option. |

The next card(s) is in format (16I5) and contains the section numbers on which isobars are to be plotted.

The last card(s) is in format (8F10.6) and contains the values of the desired isobars.

## INPUT CHECKING AND PROGRAM PRINTOUT

The printed output from XYZPLOT lists input errors and provides a record of the numerical values used to generate each view. Most error messages are self-explanatory. Two of them will be outlined here.

1. THE LINE OF SIGHT IS NOT PERPENDICULAR TO THE PLOTTING PLANE. This message is printed whenever the angle between the line-of-sight and the $x_s$-axis differs from 90 degrees by more than 1 degree. This difference is printed as "(SKEW=XX DEGREES)". A small value of "SKEW" will not cause appreciable distortion.

2. OBSERVATION POINT LIES TOO CLOSE TO BODY. This message will occur during perspective projection when XYZPLOT attempts to project a point which is very near the observation point or when the line-of-sight intersects the plotting plane at infinity.

A detailed printout is provided when plotting isobars so the user may pinpoint the location of a desired isobar. Raster coordinates (the coordinates used on the actual picture) of the points on each isobar are listed, as well as the body section on which they lie. The raster coordinate system is shown in Figure 12.

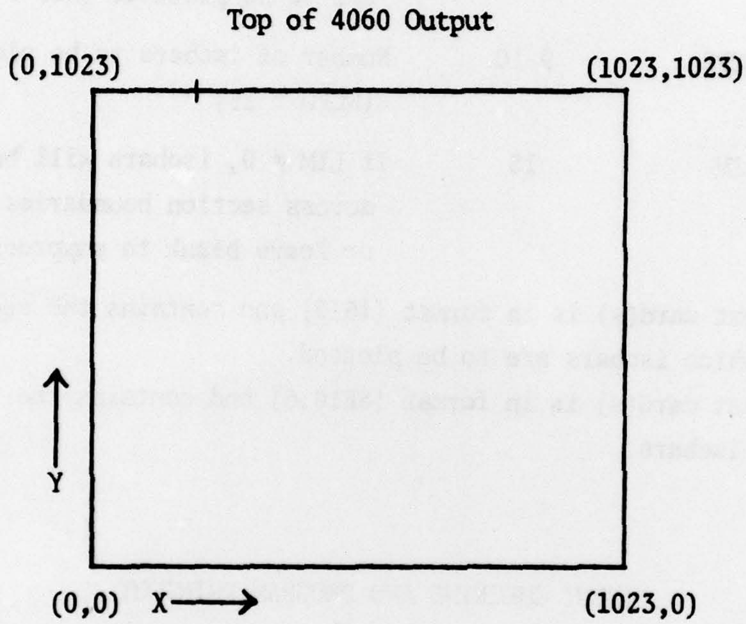



Figure 12. Raster Coordinates

## COMPUTER REQUIREMENTS

XYZPLOT is coded in CDC FORTRAN EXTENDED. Some minor reprogramming would be required to make it strictly ANSI FORTRAN. The program compiles in approximately 30 CP seconds on the CDC 6400 processor and requires a maximum of 104K octal words of storage to execute. If isobars are not going to be plotted in a given run, OVERLAY(2,5) (program ISOBAR) and its two subroutines, CONNECT and LOCATE, may be omitted, reducing the storage requirement to 75K octal words.

XYZPLOT utilizes a set of plotting routines (SCORS package) which resides in both the DTNSRDC CDC-6600 and CDC-6700 system libraries. Three scratch disk files are required in addition to a plot file, the three possible data files, and the regular input/output files.

The output for the SC-4060 microfilm plotter is written to the DTNSRDC batch plot queue, which is dumped to tape nightly. To obtain plot output, the user must submit an ADP Off-Line Request at the ADP Control Center (the request forms are available at the ADP Control Center window). Figure 13 shows an ADP Off-Line Request with the required information shown by question marks. The user will generally check both the film and hardcopy boxes (in order to obtain both film and paper output), and the Tape ID must be FILMPL-6700 or FILMPL-6600, depending on which machine the job was run on. The number of frames is supplied on the XYZPLOT printout.

**ADP OFF-LINE REQUEST NDW-NSRDC-10462/31**

| | | | |
|---|---|---|---|
| DATE ? | JOB ORDER NO. ? | | TAPE I.D. ? |
| USER I.D. ? | CODE ? | EXT. ? | CONFIDENTIAL ☐ |
| USERS NAME ? | JOBNAME ? | | SECRET ☐ |
| ☐ KEYPUNCH<br>☐ 26 ☐ 29<br>☐ VERIFY<br>☐ CONVERT TO<br>☐ 26 ☐ 29<br>☐ LIST<br>☐ REPRODUCE<br>☐ INTERPRET<br>☐ ENDPUNCH | OCR<br>☐ DOC/TAPE<br>☐ PRINT<br>☐ PUNCH<br>ROUTINE ____<br>CHAR. SIZE ____<br>NO. FILES ____<br>NO. COPIES ____ | SC4060<br>? FILM<br>NO. FRAMES ?<br>SPECIAL INSTRUCTIONS<br><br>OPERATOR COMMENTS | ROUTINE ____<br>? HARDCOPY<br>FILES ____ |

GPO 881-439

Figure 13. ADP Off-Line Request

Table 3 shows the DTNSRDC SCOPE 3.4 control card setup for a compile, load, and go type of run.

TABLE 3 - COMPILE, LOAD AND GO CONTROL CARDS

```
JOBNAME,CM104000,† T250.                  *User's JOB CARD*
CHARGE,CXXX,PPPPPPPPPP,RS,B.              *User's CHARGE CARD*
RFL,45000.                                *CXXX is user's ID, PPPPPPPPPP is user's
                                           job number*
ATTACH,TAPE2,BODYPOINTS,ID=CXXX.          *SURFACE ELEMENT POINTS (if read from
                                           disk file)*
ATTACH,TAPE4,OUTLINE,ID=CXXX.             *OUTLINE POINTS (if read from disk file)*
ATTACH,TAPE50,DATA,ID=CXXX.               *STREAMLINE/ISOBAR Data (if required)*
FTN,T,A,PL=20000.
ATTACH,SC4020.
RFL,104000.†
LDSET,LIB=SC4020,PRESET=NGINF.
LGO.
"  7/8/9  END OF RECORD
     XYZPLOT SOURCE DECK
"  7/8/9  END OF RECORD
       DATA
"  6/7/8/9  END OF FILE
```

† 75000 if OVERLAY(2,5) and its subroutines are removed.

If the program is to be used often, it is advisable to execute it from an absolute overlay file. The following deck setup may be used to create this file:

```
JOBNAME,CM104000,T50.
CHARGE,CXXX,PPPPPPPPPP,CC,B.
FTN,T,A,PL=10000.
REQUEST,GOFILE,*PF.
ATTACH,SC4020.
LDSET,LIB=SC4020,PRESET=NGINF.
LOAD,LGO.
NOGO.
CATALOG,GOFILE,XYZPLOTGOFILE,ID=CXXX,AC=PPPPPPPPPP.
"  7/8/9  END OF RECORD
     XYZPLOT SOURCE DECK
"  6/7/8/9  END OF FILE
```

Execution may then be accomplished by the following two control cards:

```
ATTACH,GOFILE,XYZPLOTGOFILE,ID=CXXX.
GOFILE.
```

GOFILE is the local file name of the XYZPLOT overlay file and is the only name that may be used.

Execution times are difficult to estimate because of the large number of factors involved. A conservative time estimate would be 50 seconds per view, plus 30 seconds for compilation. A table of execution times accompanies the examples presented in the next section.

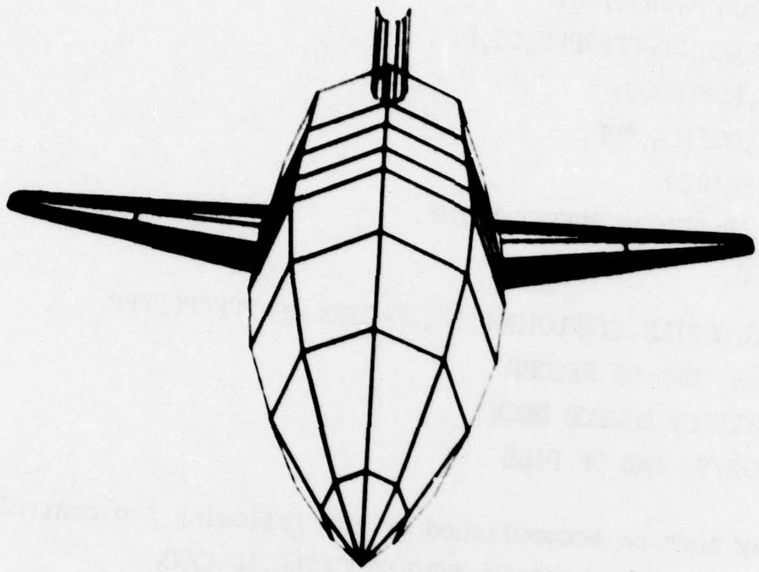
## INPUT/OUTPUT EXAMPLES

Applications of XYZPLOT are demonstrated in this section. Output examples are given for each of its various uses, and the input which generated the on-body streamline example is shown.

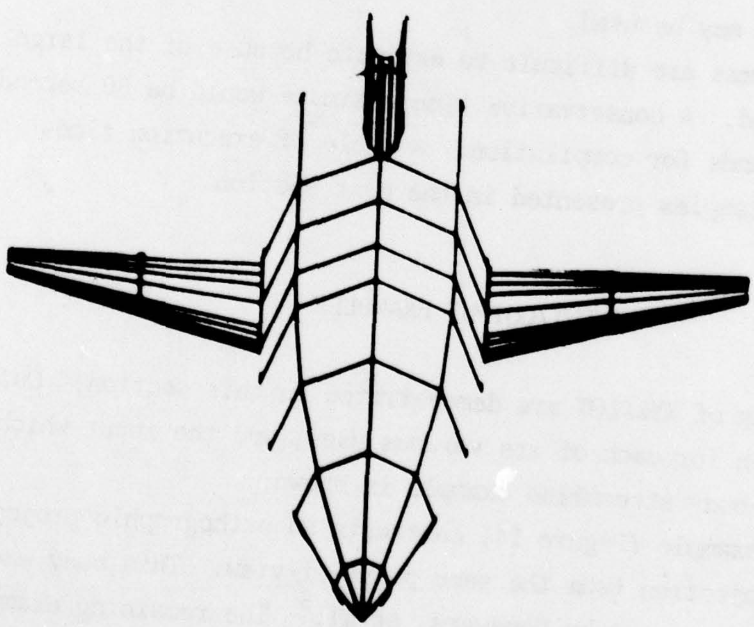
The first example (Figure 14) contrasts an orthographic projection with a perspective projection from the same point-of-view. This body was a test example in a recent report by Woodward, et al.[5] The remaining examples are in perspective.

---

[5] Woodward, F.A., Dvorak, F.A., and Geller, E.W., "A Computer Program for Three-Dimensional Lifting Bodies in Subsonic Inviscid Flow," Flow Research, Inc., Kent, Washington, Rept. USAAMRDL-TR-74-18 (April 1974).



PERSPECTIVE



ORTHOGRAPHIC

Figure 14. Comparison of Perspective and Orthographic Projections

Figure 15 shows a sphere with off-body streamlines. The size ratio (SR parameter on the sixth plotting information card) was set to 0.4 to allow room on the picture for the streamlines to pass around the body.

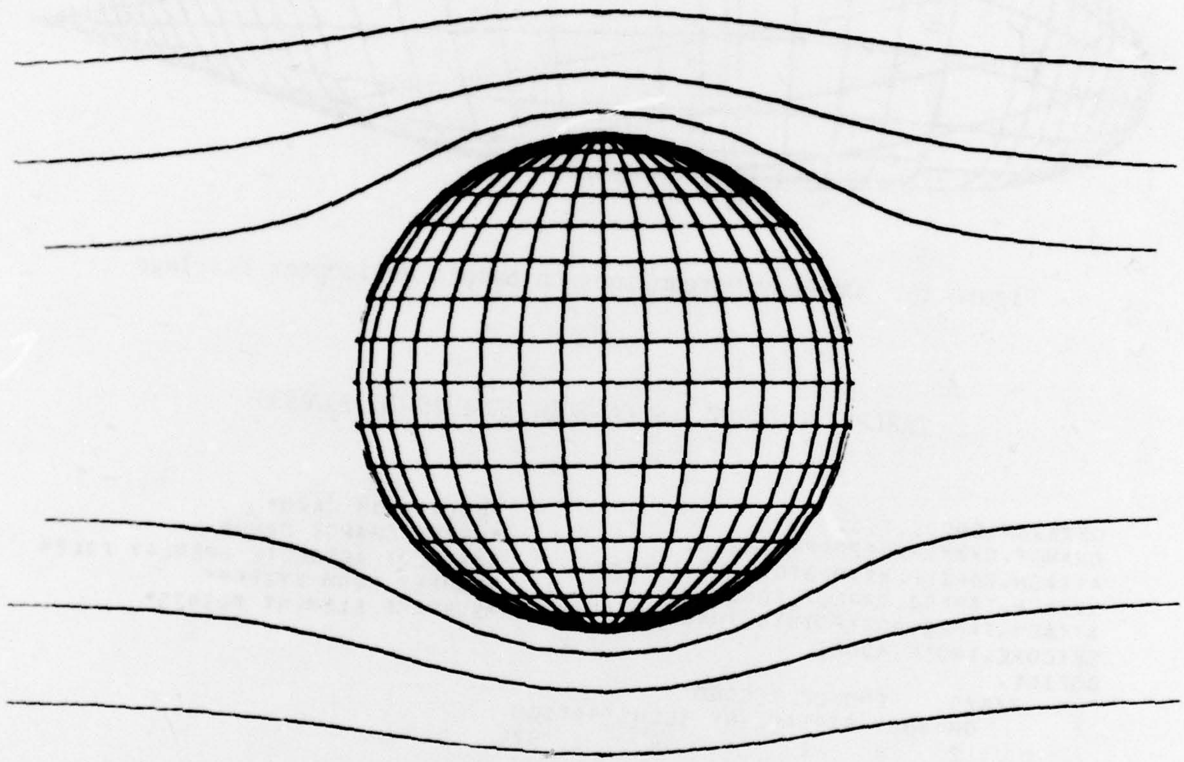


Figure 15. Sphere with Off-Body Streamlines

On-body streamlines are shown on a sample helicopter fuselage in Figure 16. The input is shown in Table 4. Body and streamline data were read from disk files.

The isobar example is Figure 17. It shows an isobar on a helicopter rotor hub fairing: the upper picture shows the results without the connection option; the lower picture shows a successful application of the connection option to connect the isobars across the section boundaries.

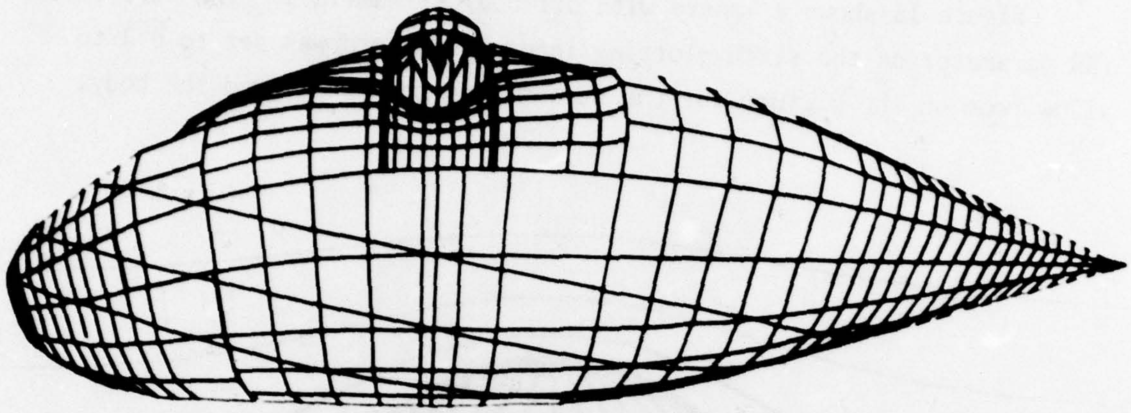


Figure 16. On-Body Streamlines on Sample Helicopter Fuselage

TABLE 4 - INPUT FOR ON-BODY STREAMLINE EXAMPLE

```
CXXX,CM104000,T50.                          *USERS JOB CARD*
CHARGE,CXXX,PPPPPPPPPPP,RS,B.               *USERS CHARGE CARD*
ATTACH,GOFILE,XYZPLOTGOFILE,ID=CXXX.        *XYZPLOT ABSOLUTE OVERLAY FILE*
ATTACH,TAPE50,TAPE17,ID=CXXX.               *TAPE17 FROM XYZPFP*
ATTACH,TAPE2,BODYPOINTS,ID=CXXX.            *SURFACE ELEMENT POINTS*
SETCORE,INDEF,ADDR.
GOFILE.
-    7/8/9     END OF RECORD
        ON-BODY STREAMLINE ILLUSTRATION
   1     2     0     2     1     4     1  576     0.
NAME       CODE        PHONE
     BLANK CARD                 (NO TITLE ON FRAME)
   1     1     0     0
  -20.                 20.                    7.3
  -20.                  0.                    0.
  -40.                  0.                    0.
    0.             0.               0.                 0.               1.
   9     1
   1     2     3     4     5     6     7     8     9
  -8.         0.          -1.
-    7/8/9     END OF RECORD
-  6/7/8/9     END OF FILE
```

(IF MORE THAN ONE VIEW WAS DESIRED, THE NEXT SET OF PLOTTING INFORMATION CARDS WOULD FOLLOW THE LAST END OF RECORD CARD, ETC.)

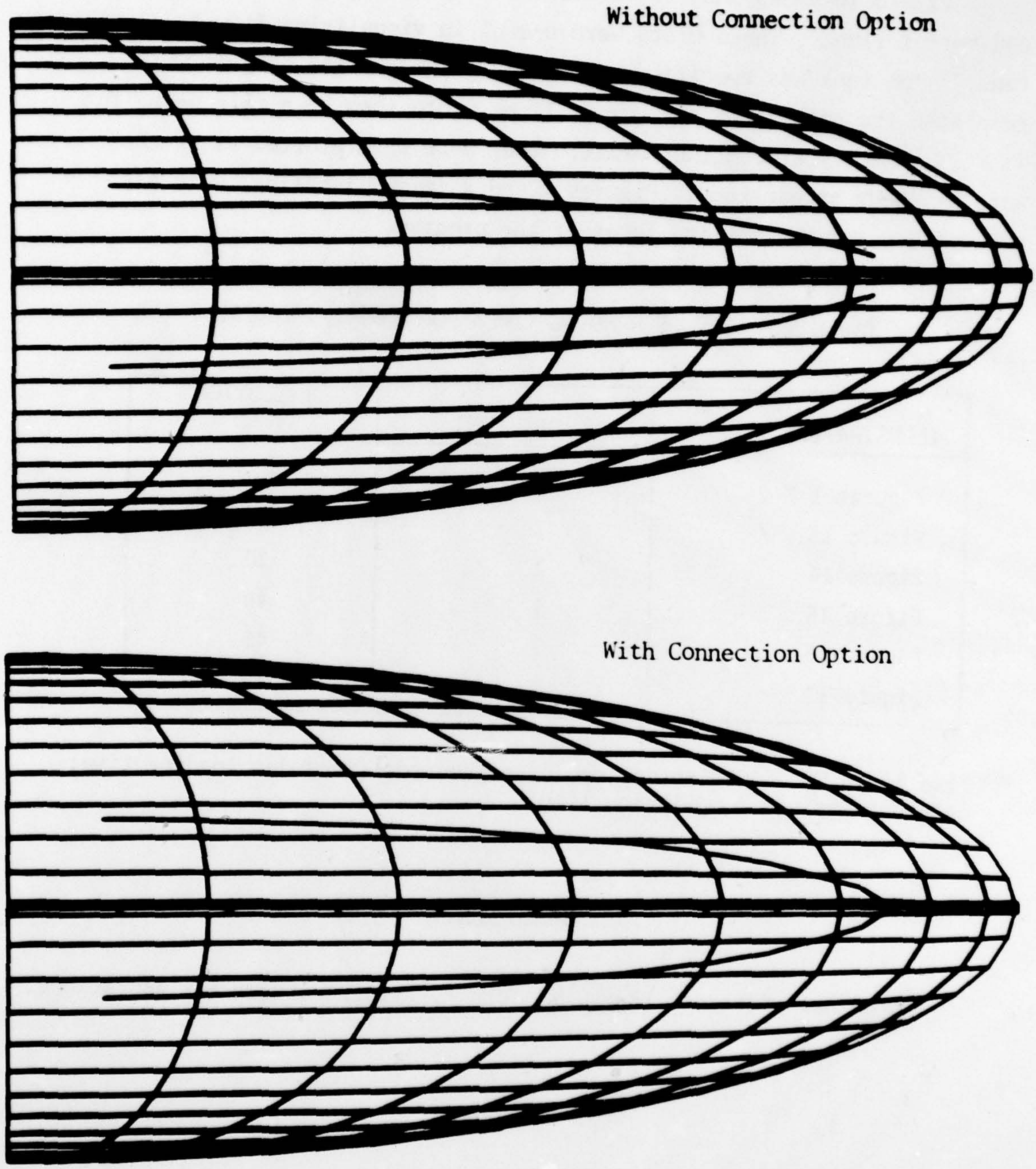



Figure 17. Isobar on Helicopter Rotor Hub Fairing

Figure 18 shows the use of XYZPLOT in plotting body outlines, pathlines, and vortex lines. These plots were useful in visualizing flow in a rotating tank.[6] The tank was specified by outline point and the program which generated the path lines and vortex lines wrote them on a file using the XYZPLOT off-body streamline format. They were then plotted as if they were off-body streamlines. Figures 1 and 2 (minus labeling) were also generated using the outline facet of the program.

TABLE 5 - LIST OF RUNNING TIMES FOR SAMPLE PROBLEMS

| ILLUSTRATION | NO. OF VIEWS | EXECUTION TIME* |
|---|---|---|
| Figures 1 & 2 | 2 | 19 |
| Figure 13 | 2 | 23 |
| Figure 14 | 1 | 20 |
| Figure 15 | 1 | 40 |
| Figure 16 | 2 | 46 |
| Figure 17 | 4 | 30 |

* Time is in CDC 6400 central processor seconds (includes loading time; does not include compilation time).


## ACKNOWLEDGMENT

The author wishes to thank Mr. John K. Reingruber for his assistance.


[6] Lugt, H.J., Haussling, H.J., and Ohring, S., "Laminar Flow Circulation in a Rotating Tank with a Spinning Cover," Naval Ship Research and Development Center, Washington, D.C., Report No. 3797 (February 1972).

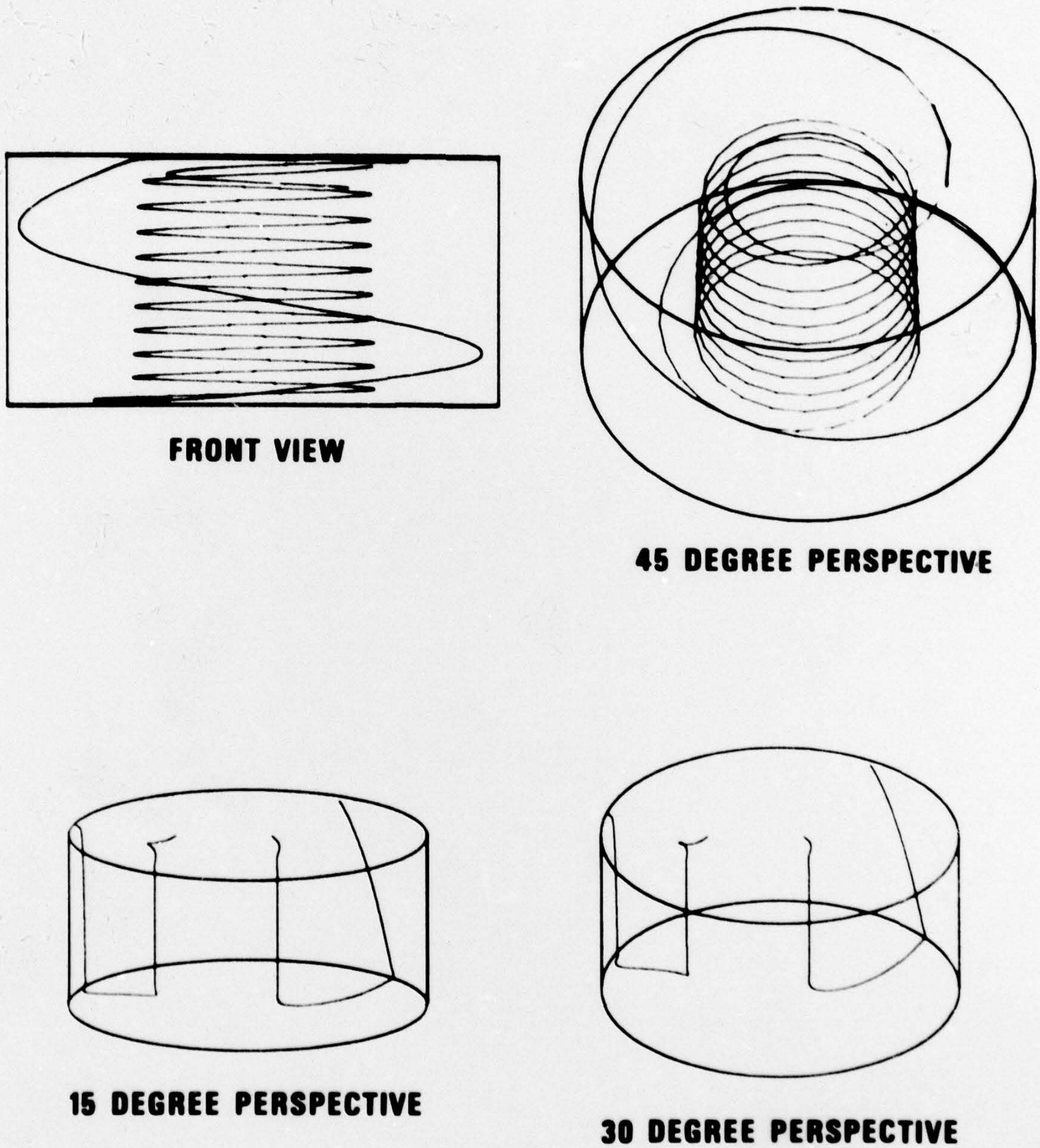



Figure 18. Rotating Tank Pathline and Vortex Lines

## INITIAL DISTRIBUTION

Copies:

| | | |
|---|---|---|
| 1 | 011 | |
| 1 | 1500 | |
| 1 | 1521 | P. Pien |
| 1 | 1524 | J. Grant |
| 3 | 1552 | T. Huang |
| | | C. Von Kerczek |
| | | N. Groves |
| 2 | 1556 | D. Coder |
| | | J. Nelka |
| 1 | 1600 | |
| 1 | 1620 | H. Robertson |
| 1 | 1650 | B. Ellis |
| 1 | 1670 | A. Anderson |
| 1 | 1700 | |
| 1 | 1725 | R.F. Jones |
| 1 | 1800 | |
| 2 | 1802 | F. Frenkiel |
| | | F. Theilheimer |
| 1 | 1805 | |
| 1 | 1809.3 | |
| 1 | 1830 | |
| 1 | 1840 | |
| 10 | 1843 | |
| 1 | 1844 | |
| 1 | 1850 | |
| 1 | 1860 | |
| 1 | 1880 | |
| 1 | 1890 | |
| 1 | 1900 | |
| 1 | 1942 | B. Bowers |
| 1 | 2732 | R. Wavle |
| 1 | 1833 | R. Chen |

DTNSRDC ISSUES THREE TYPES OF REPORTS

1. DTNSRDC REPORTS, A FORMAL SERIES, CONTAIN INFORMATION OF PERMANENT TECHNICAL VALUE. THEY CARRY A CONSECUTIVE NUMERICAL IDENTIFICATION REGARDLESS OF THEIR CLASSIFICATION OR THE ORIGINATING DEPARTMENT.

2. DEPARTMENTAL REPORTS, A SEMIFORMAL SERIES, CONTAIN INFORMATION OF A PRELIMINARY, TEMPORARY, OR PROPRIETARY NATURE OR OF LIMITED INTEREST OR SIGNIFICANCE. THEY CARRY A DEPARTMENTAL ALPHANUMERICAL IDENTIFICATION.

3. TECHNICAL MEMORANDA, AN INFORMAL SERIES, CONTAIN TECHNICAL DOCUMENTATION OF LIMITED USE AND INTEREST. THEY ARE PRIMARILY WORKING PAPERS INTENDED FOR INTERNAL USE. THEY CARRY AN IDENTIFYING NUMBER WHICH INDICATES THEIR TYPE AND THE NUMERICAL CODE OF THE ORIGINATING DEPARTMENT. ANY DISTRIBUTION OUTSIDE DTNSRDC MUST BE APPROVED BY THE HEAD OF THE ORIGINATING DEPARTMENT ON A CASE-BY-CASE BASIS.